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HUMAN FACTORS EVALUATION OF SUBMARINE ESCAPE: IA. INDIVIDUAL AND GROUP ESCAPE WITH THE BRITISH SUBMARINE ESCAPE IMMERSION SUIT AND THE STEINKE HOOD UNDER CONDITIONS OF SIDE AND TUBE EGRESS

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SUBMARINE MEDICAL RESEARCH LABORATORY
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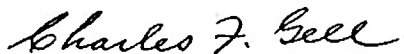
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SUMMARY PAGE

THE PROBLEM

To evaluate the compatibility of the British Mark VII Submarine Escape Immersion Suit (SEIS) with existing United States Navy escape trunk configurations and procedures.

FINDINGS

The SEIS may be successfully used with existing escape trunk configurations, however, the depth from which escapes can be made without danger of decompression sickness is limited by the size of the escape team and trunk configuration.

APPLICATION

The research described in this report should contribute to the development of an improved submarine escape system incorporating exposure protection and other desirable features of the British SEIS.

ABSTRACT

The compatibility of the British Mark VII Submarine Escape Immersion Suit (SEIS) with side egress and tube egress United States Navy escape trunk configurations was evaluated. Egress time with the SEIS was compared to that with the Steinke Hood under conditions of individual and group escape (1, 2, and 3 man teams). Escape time increased linearly as a function of team size. For both escape appliances a significant interaction was obtained between escape trunk configuration and team size. More rapid escapes were made by three-man teams from tube egress than from side egress escape trunk configurations; there was no difference for one-man escapes. For two-man teams, escapes were more rapid from the tube egress configuration with the Steinke Hood; there was no difference between configurations with the SEIS. While the depth from which escapes can be made without danger of adverse physiological effects is limited by the size of the escape team and the trunk configuration, there is no evidence to indicate that existing escape capability with the Steinke Hood would be reduced by substituting the SEIS which provides greater exposure protection.

HUMAN FACTORS EVALUATION OF SUBMARINE ESCAPE:

1A. Individual and Group Escape with the British Submarine
Escape Immersion Suit and the Steinke Hood
Under Conditions of Side and Tube Egress

INTRODUCTION

Although submarine casualties are relatively infrequent, the necessity of procedures for abandoning bottomed submarines must be recognized. Since 1851, when the first escape was accomplished, many devices and techniques for increasing the ability to escape safely have been developed. The Momsen Lung, the technique of buoyant ascent, and the Steinke Hood have been successively adopted for use by the United States Navy. While such devices have augmented safety of escape from depth, they offer the Navy submariner little protection from the hostile environment through which he must pass prior to reaching the surface and virtually no exposure protection once he has reached the surface.

The British Royal Navy has developed a submarine escape system which affords the escapee increased safety as well as exposure protection. The system, Submarine Escape and Immersion Equipment (SEIE), involves a combination of a modified single-man escape tower, together with a specially designed Submarine Escape Immersion Suit (SEIS) and Hood Inflation System (HIS). The suit, shown in Figure 1, consists of a buoyancy stole and hood which are inflated prior to escape and an exposure protective component which is inflated when the escapee reaches the surface. The SEIS stole and hood are similar to those of the Steinke Hood (Figure 2). The configuration of the submarine escape tower, shown in Figure 3, provides for top hatch egress and for automatic inflation of the stole and hood by the HIS.

Current escape philosophy of the British Royal Navy and the United States Navy differ in that the former emphasizes individual escape and the latter group escape (Elliott, 1966). Furthermore, there are basic differences in the design of the escape trunks. While the British single man escape towers are designed for a top egress, the United States Navy's submarine escape trunks are generally designed for a side or tube egress. Additionally, the United States Navy's submarine escape trunks differ in configuration across classes of submarines.

In an investigation of the physiological effects of immersion under varying environmental conditions while wearing the SEIS, Hall, Nobel, and Santa Maria (1968) confirmed that the use of the suit can reduce exposure casualties. The present study is directed toward the evaluation of the human factors aspect of the compatibility of suit, man, and escape trunk. It was designed to evaluate: (a) the feasibility of utilizing the SEIS as compared to the Steinke Hood under conditions of individual and group egress; (b) the effect of escape trunk configuration upon escape time when escapees are wearing either the SEIS or the Steinke Hood.

Zipper to Close Hood

Hood Attached to Suit

Inner Water Tight Hood

Suit Closure Zipper Terminated at Opening

Rip String

Relief Valves Venting into Hood

Buoyancy Stole Inside Suit Capacity Not Less Than 0.777 cu.ft.

Pull off Tab To Rip Strip

Stole Inflation Tube Built into Left Sleeve

Light Operated by Salt Water Battery

Open for Hood Venting

Vent for Excess Air

Vent for Excess Air

Oral Inflation Tube

CO_2 Suit Inflation Cartridge

Suit Deflation Key

Water Tight Cuffs

Pocket Containing Gloves for Use on Surface

Stole Inflation Tube Terminating in Palm of Left Hand

Elasticated at Ankles

Fig. 1. *Details of the British Mark VII Submarine Escape Immersion Suit.*

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HOOD

VIEWING WINDOW

NECK SEAL

MOUTHPIECE

2 RELIEF VALVES
FACTORY SET AT
1.5 P.S.I.

SNORKEL

ZIPPER

FLASHLIGHT
BECKET

ORAL INFLATION
and DEFLATION TUBE

SURFACE SURVIVAL
EQUIPT. STOWAGE

CHARGING INLET
CHECK VALVE

BUOYANCY
CHAMBER

WAIST BELT
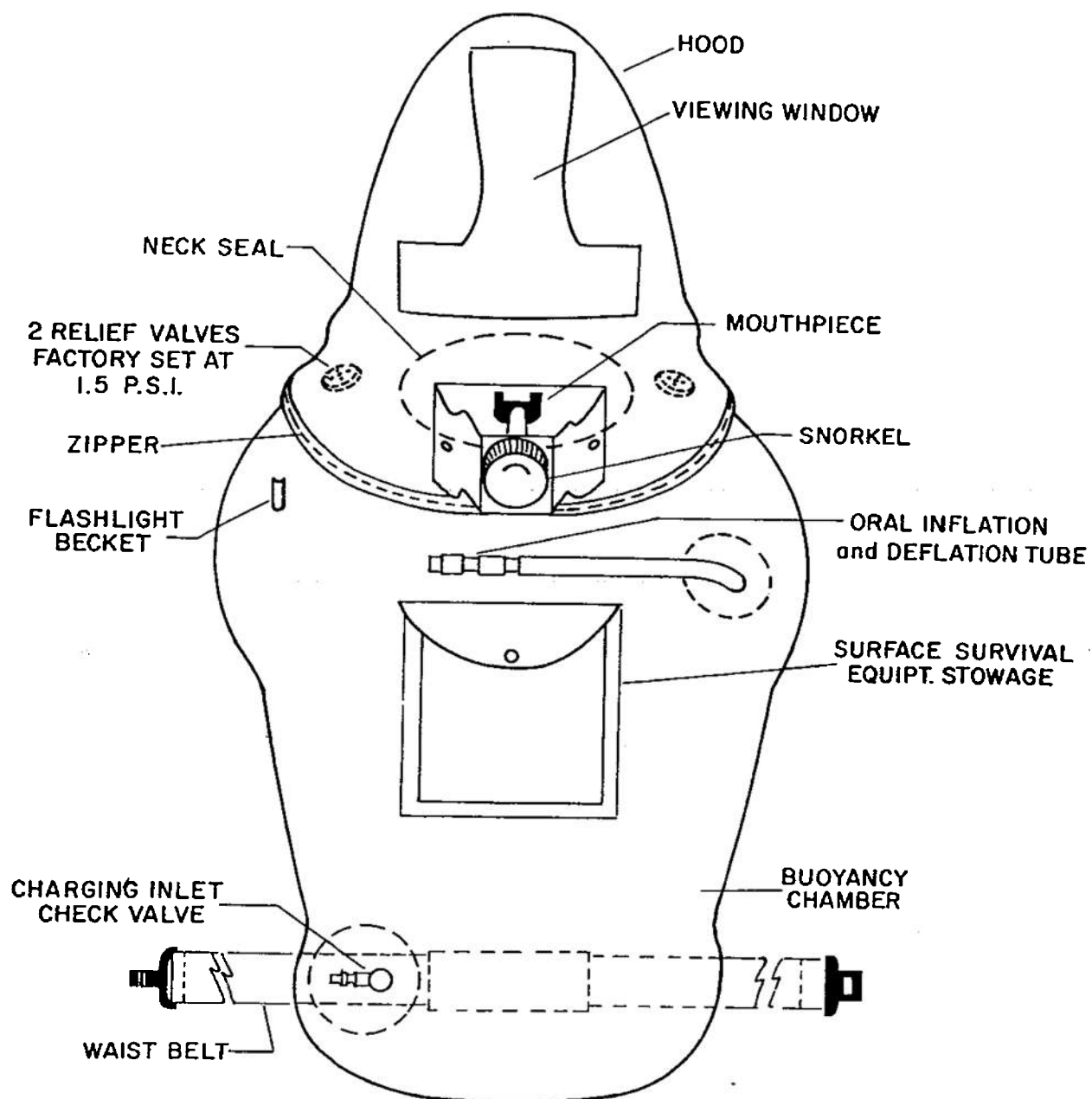
Fig. 2. Details of the Steinke Hood.

3
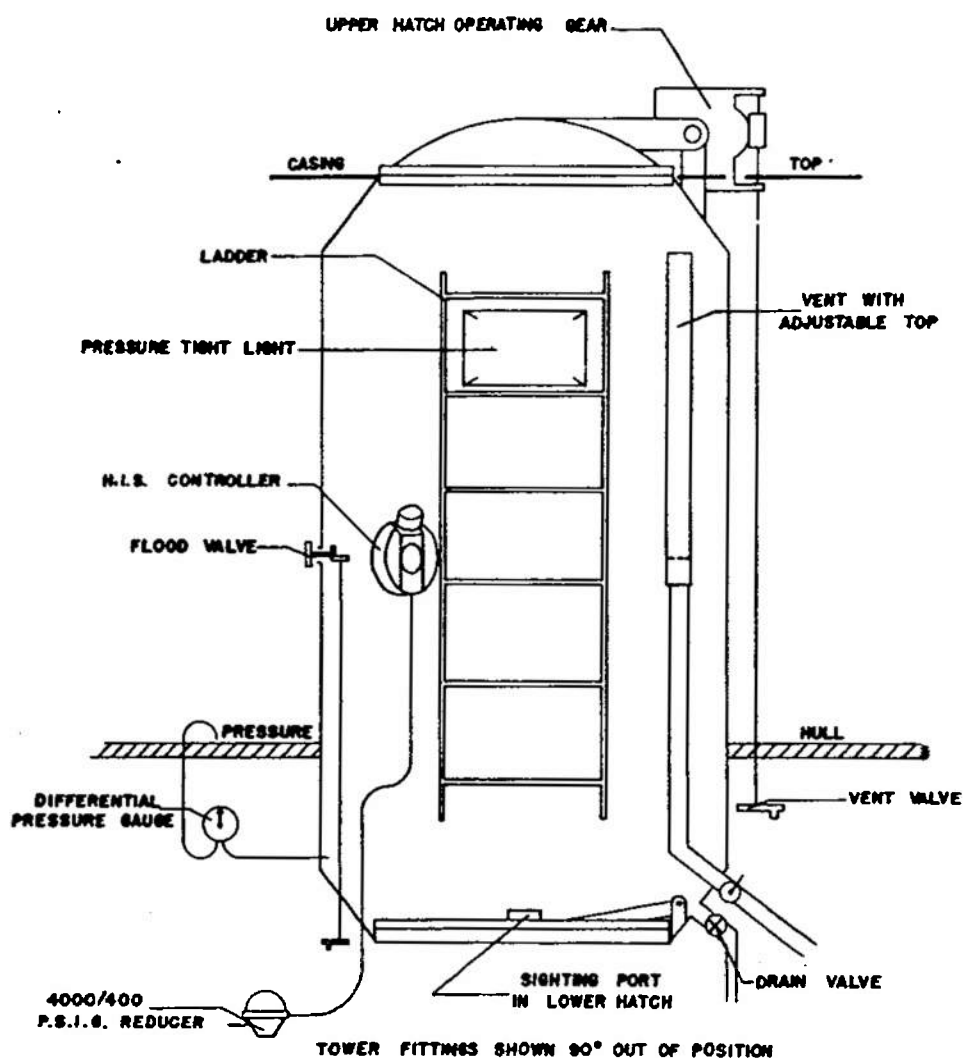
Fig. 3. *Principal Features of the British Single Man Escape Tower (From Hall, Noble and Santa Maria, 1968).*

METHOD

Subjects

Ss were 15 United States Navy Escape Training Instructors from the Submarine Escape Training Department of the Naval Submarine School in Groton. The divers were experienced in the use of the Steinke Hood and were trained in the use of the SEIS. They represent the whole population of Navy divers in the Escape Training Department familiar with the SEIS, but do not represent the general population of Navy divers or submarine crews. The instructors were formed into five teams of three Ss each.

Experimental Design

United States Navy submarine escape trunks may be classified into 22 configurations (Appendix, Figure 1). These configurations may be divided into three basic trunk types: side egress, tube

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egress, and top egress. They differ along several dimensions that might affect ease of escape: diameter of the trunk, location of the escape hatch (side or top), height of the opening above the trunk deck, presence or absence of an escape tube, and length of the escape tube. Side egress and top egress trunks are installed in conventional-type submarines, and tube egress trunks are installed in nuclear-type submarines. Since relatively few United States Navy submarines have top egress trunks, this study was concerned only with side egress and tube egress trunks. It was assumed that egress through the tube would be more difficult than through the side hatch, and that a study of extreme representatives of each of the two types of trunks would adequately demonstrate the kinds and magnitude of problems associated with use of the SEIS in United States Navy submarines. Tube egress trunks are designed to hold four men; side egress trunks are designed to hold three men. Because of practical considerations, such as the difficulty of retaining Ss throughout the study and the total number of escapes which would have to be made, the present study was limited to groups of 1, 2, and 3 men.

The two major independent variables, trunk type and group size were manipulated within a Treatments X Treatments experimental design. Table 1 summarizes the design. Ss made two one-man escapes, four two-man escapes, and six three-man escapes from each trunk type. As indicated in Table 1, the position of the S was counterbalanced for two-man and three-man escapes. There were five

replications of the basic design for the SEIS and two for the Steinke Hood.

Apparatus

To reproduce as closely as possible the conditions under which escape from a bottomed submarine is made, an escape trunk simulator was constructed. Its major features and dimensions are shown in Figure 4. The tube egress simulator consisted of the larger cylinder and the escape tube. The internal dimensions of the cylinder were those of a 571-Class submarine. The length and angle of the escape tube and the height of the entrance to the escape tube, reproduce those found on submarines of the 616-Class and of the 637-Class respectively. The side egress escape trunk was composed of the cylindrical insert which constrained the size of the simulator, the side hatch, and the metal framework which simulates decking. The dimensions of the components for this simulator are those of a 405-Class submarine.

Since there is little variation in the configuration of the interiors of side egress or tube egress submarine escape trunks, the interiors of the 405-Class and the 571-Class submarines were taken as models respectively. For the side egress trunk wooden mock-ups were constructed of tubing, controls, gauges, knobs, etc., and were mounted on the insert. For the nuclear-type trunk, actual components were mounted on the basic shell. A plexiglass hatch was fabricated for each configuration. These hatches were friction loaded so that a force of approximately 20 lbs. was required to open

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Table 1. Experimental Design[1]

Group Size	Trunk Configuration					
	Side Egress			Tube Egress		
1	A	B	C	A	B	C
2	b–A c–A	a–B c–B	a–C b–C	b–A c–A	a–B c–B	a–C b–C
3	bc–A cb–A	ac–B ca–B	ab–C ba–C	bc–A cb–A	ac–B ca–B	ab–C ba–C

[1] Letters represent escape position of three different subjects; A, B, C. Capital letters indicate the last man to escape. Numerals indicate number of subjects attempting a group escape.
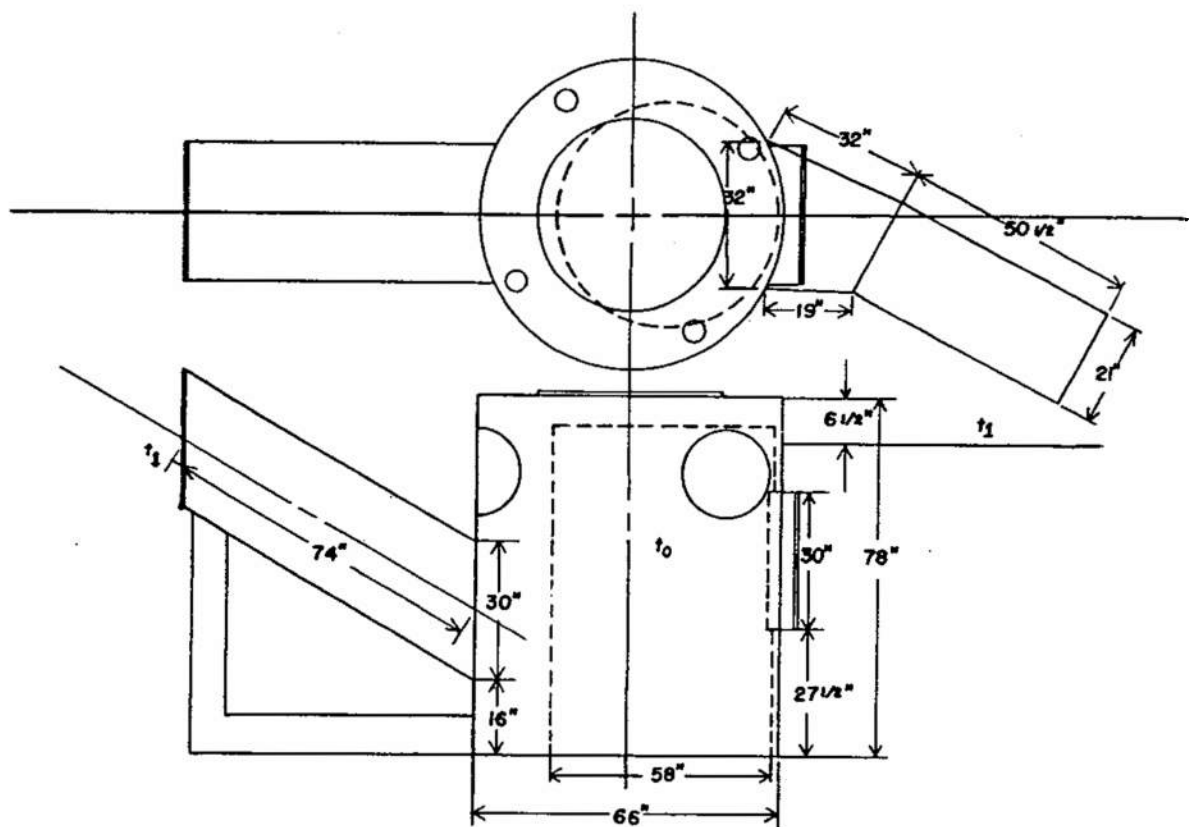

Fig. 4. Diagram of the Submarine Medical Research Laboratory Escape Trunk Simulator, showing the removable insert. Interior details are not shown. $\underline{t}$ indicates data collection point.

them. The decking was simulated by constructing a rectangular frame from tubing and mounting it above the side egress hatch (Figure 4). The simulator was submerged in 10 feet of water in a pool at the Naval Underwater Sound Laboratory, New London (Figures 5 and 6).

The escape procedure was monitored by two underwater closed-circuit television cameras. One camera was mounted within the simulator and the other external to it. Internal trunk lighting was provided by an LT-6 thallium oxide underwater lamp and

exterior lighting by two underwater LQ10 quartz iodide lamps. Four closed-circuit TV monitors were used for recording data and for general observations. Two Ampex Video Tape recorders, Model 600, were included in the system.

A Simplex Model CPR Time Recorder, three Scientific Prototype 301G Interval Recorders, a Brush Recorder Mark 220, and a specially constructed keyboard were used for data recording. The time recorder printed elapsed time in hundreds of a minute. The
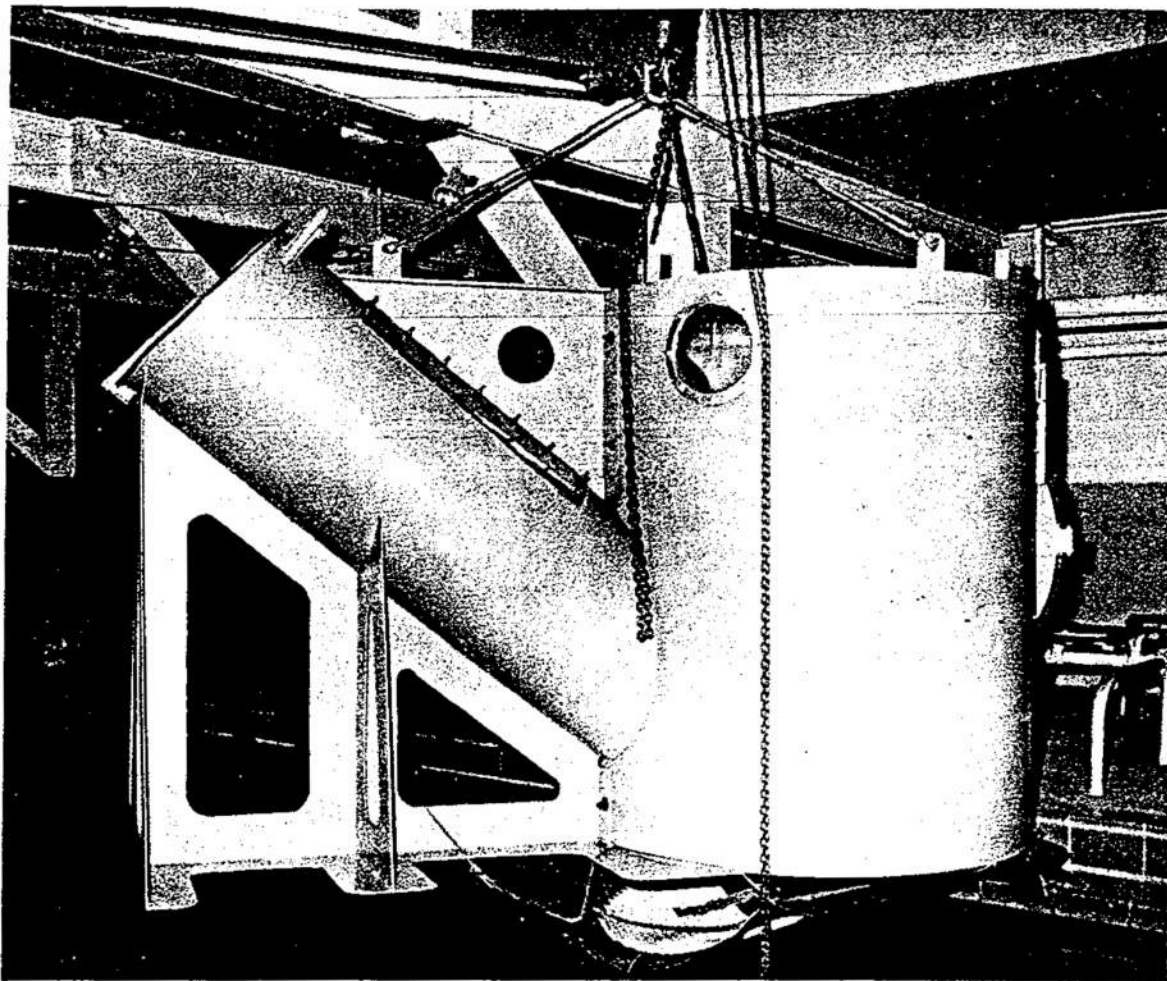
Fig. 5. Naval Submarine Medical Research Laboratory Escape Trunk Simulator being lowered into the pool at the Naval Underwater Sound Laboratory.
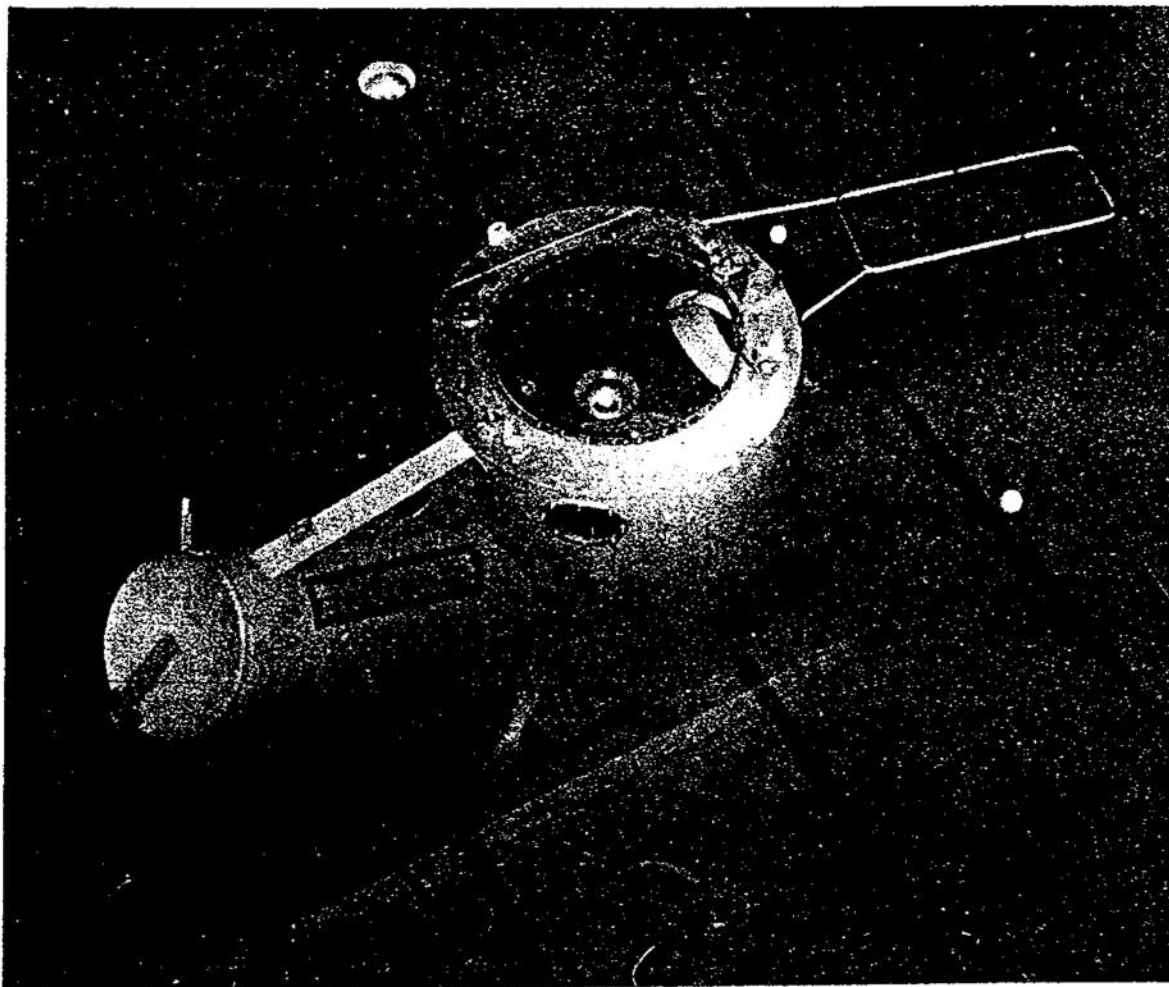
Fig. 6. Simulator submerged in 10 feet of water at the Naval Underwater Sound Laboratory.

Brush Recorder in combination with the keyboard provided a record of the time sequence for each subject, as well as a validity check on the time recorder. The onset of a signal light mounted inside the escape trunk served as a 10 second warning signal for the Ss. The offset of the signal light was synchronized with the onset of the time recorder.

All Ss wore the British Mark VII Submarine Escape Immersion Suit

(SEIS) or the Steinke Hood (Figure 7). The HIS utilized in the British escape trunk was not simulated. Hood and stole inflation was accomplished by charging the appliance with compressed air from supply lines in the simulator. The external compressed air supply also provided a 19-inch bubble within the escape trunk. Contact between the Ss subjects in the escape trunk and the surface was maintained by means of a Yack/Yack Model 10-120 underwater communication system.

Fig. 7. Subjects wearing the Steinke Hood (right) and the SEIS (left).

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Procedure

All $\underline{S}$s inflated their appliance immediately. upon entering the trunk and then reported that they were ready for escape. At the offset of the signal light (t_0), the $\underline{S}$s began escape. For a side egress the first man to escape pushed the hatch open and left the trunk. He then passed through the simulated decking to the surface. The remaining team members ducked through the opening and proceeded through the decking to the surface. With the tube egress the first man to escape ducked into the tube, pushed open the hatch at the end of the tube and proceeded to the surface. The remaining escapees followed. The experimenter observed the escape on the TV monitors and recorded the data from them. The data points for timing an egress are indicated in Figure 4.

The order of running the teams of $\underline{S}$s was counterbalanced. Three teams escaped from the tube egress trunk first and the remaining teams from the side egress trunk first. On any one trial an $\underline{S}$ entered one of the two trunks alone or with one or two other $\underline{S}$s. The order in which the individuals and two or three-man teams were run was randomized for each three-man team.

Since primary interest focused upon the SEIS, these data were collected first. Subsequently, data were collected for two teams wearing the Steinke Hood. The procedure was the same for both appliances.

RESULTS

The measure of escape time was taken as the time from the offset of the ready signal, t_0 (beginning of escape), to the completion of escape, t_1. For the side egress simulation, t_1 was defined as the time at which the escapee's chest cleared the decking; for the tube egress simulation it was taken as the time at which the chest cleared the escape tube. The data appear in the Appendix, Table 1.

SEIS. Mean total escape times for team size and for trunk configuration are summarized in Table 2 and Figure 8. Differences between the means were tested with a Treatments X Treatments analysis of variance (Table 3). The interaction between team size and trunk configuration and the linear component of the interaction were statistically significant $(p<.01)$. Differences between the means for team size and for trunk configuration, and the linear trend for team size were also significant $(p<.01)$. Tests of the differences between the means for trunk configurations were significant for three-man teams $(\underline{t} = 4.43, \underline{df} = 174, \underline{p}<.05)$ but were not significant for two-man teams $(\underline{t} = 1.09, \underline{df} = 174, p>.05)$ or for one-man teams $(\underline{t} = 0.20, \underline{df} = 174, p>.05)$. Thus for both the tube egress and the side egress trunks there was a significant linear increase in egress time as team size increased. Three-man teams required significantly longer egress times for side egress than for tube egress, but there was no difference for two-man teams or for one-man.

To assess the effect of egress position of any $\underline{S}$ within a team, two additional analyses of variance were performed. The mean time for the first man to egress was evaluated across all three team sizes for both trunk configurations (Table 4). A similar analysis was

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Table 2. SEIS: Means and Standard Deviations of Escape Time[1] by
Team Size and Position for Side Egress (S) and Tube Egress (T)
Type Escape Trunk Simulations

Team Size	Trunk	Position					
		1		2		3	
		$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ
1	S	11.63	4.51				
	T	11.94	3.70				
2	S	10.46	3.68	21.31	5.64		
	T	10.83	3.58	19.61	8.30		
3	S	9.89	3.73	20.16	4.79	30.91	5.96
	T	10.88	4.47	16.86	5.40	24.00	7.14

[1] All escape times are in seconds.

Table 3. SEIS: Analysis of Variance for Team Size and Trunk Configuration

Source	df	MS	F
Team Size (T)	2	3697.34	100.18 **
Linear	1	7366.47	199.59 **
Quadratic	1	28.22	0.76
Trunk Configuration (C)	1	344.73	9.34 **
T X C	2	208.07	5.64 **
Linear X C	1	390.96	10.59 **
Quadratic X C	1	25.17	0.68
Error	174	36.91	

** Significant at beyond the .01 level.

Table 4. SEIS: Analysis of Variance for the First Man to Escape
and Trunk Configuration

Source	df	MS	F
Team Size (T)	2	33.38	2.12
Trunk Configuration (C)	1	14.22	0.90
T X C	2	2.17	0.14
Error	174	15.73	
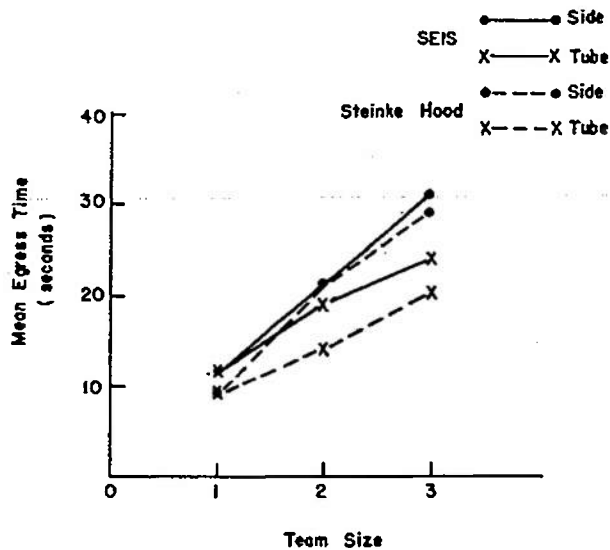
Fig. 8. Mean egress times for one, two and three-man escapes from side egress and tube egress escape trunks with the SEIS and the Steinke Hood.

was not possible to evaluate the third position.

Steinke Hood. Table 6 and Figure 8 summarize the mean total escape time for team size and trunk configuration. Treatment of the data for the Steinke Hood was similar to that for the SEIS. Differences between the means were assessed by a Treatments X Treatments analysis of variance (Table 7).

Table 5. SEIS: Analysis of Variance for the Second Man to Escape and Trunk Configuration

Source	df	MS	F
Team Size (T)	1	113.88	2.98
Configuration (C)	1	187.75	4.91*
T X C	1	18.80	0.49
Error	116	38.25	

made across two and three-man teams for the second man (Table 5). Only the difference for trunk configuration for the second man was significant ($p < .05$). Egress time for the first and second man to escape was not effected by team size. Escape time for the second man was, however, significantly longer for side egress. Since there were no teams with more than three men, it

* Significant at beyond the .05 level.

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Table 6. Steinke Hood: Means and Standard Deviations of Escape Time[1] by
Team Size and Position for Side Egress (S) and Tube Egress (T)
Trunk Simulations

Team Size	Trunk	Position					
		1		2		3	
		$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
1	S	9.93	2.65				
	T	9.91	2.49				
2	S	11.32	2.21	21.42	3.87		
	T	9.22	2.68	13.82	3.25		
3	S	10.50	2.60	19.87	3.21	29.28	3.45
	T	8.90	2.37	13.73	3.51	19.98	4.19

[1] All escape times are in seconds.

Table 7. Steinke Hood: Analysis of Variance for Team Size
and Trunk Configuration

Source	df	MS	F
Team Size (T)	2	1298.97	114.04**
Linear	1	2598.02	227.87**
Quadratic	1	1.91	0.17
Trunk Configuration (C)	1	572.35	50.24**
T X C	2	146.58	12.87**
Linear X C	1	258.54	22.69**
Quadratic X C	1	34.61	3.04
Error	66	11.39	

** Significant at beyond the .01 level.

The interaction between team size and trunk configuration was significant, as was the linear component of the interaction ($p < .01$). Significant differences was also obtained for the means of team size, trunk configuration, and team size linear trend ($p < .01$). t tests of differences between the means for trunk configuration were significant for three-man teams ($t = 6.77$, $df = 66$, $p < .01$) and two-man teams ($t = 5.53$, $df = 66$, $p < .01$) but were not significant for one-man ($t = 0.01$, $df = 66$, $p > .05$). As team size increased there was a significant linear increase in egress time for both side egress and tube egress. Three-man teams and two-man teams took significantly longer to escape from the side egress trunk than from the tube egress trunk; there was no significant difference for one man.

The effects of egress position upon escape time were evaluated across team size for both trunk configurations. Analysis of variance resulted in no significant differences in mean escape time ($p > .05$) for either the first man (Table 8) or the second man (Table 9). Significant differences between trunk configurations were obtained for both the first man ($p < .05$) and the second man ($p < .01$). Team size had no effect upon egress time for either the first man or the second man to escape. Regardless of egress position, escape time was significantly longer for the side egress trunk than for the tube egress trunk. It was not possible to evaluate the third position.

Table 8. Steinke Hood: Analysis of Variance for the First Man to Escape and Trunk Configuration

Source	df	MS	F
Team Size (T)	2	1.98	0.31
Trunk Configuration (C)	1	27.75	4.42*
T X C	2	7.14	1.14
Error	66	6.24	

* Significant at beyond the .05 level.

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Table 9. Steinke Hood: Analysis of Variance for the Second Man to Escape and Trunk Configuration

Source	df	MS	F
Team Size (T)	1	8.08	0.67
Trunk Configuration (C)	1	566.50	47.01 **
T X C	1	6.38	0.53
Error	44	12.05	

** Significant at beyond the .01 level

DISCUSSION

The primary concerns of the present study were the effect of trunk configuration upon ease of egress, the feasibility of collective escape while wearing the SEIS, and the comparison of escape capability with the SEIS and the Steinke Hood. In general the results were identical for both escape appliances. Significant interactions were obtained between team size and trunk configuration with the SEIS and the Steinke Hood. These interactions reflect the fact that the superiority of tube egress over side egress increased with team size. Comparing escape time across configurations, we find that mean escape time was significantly shorter for three-man tube egress escapes than for three-man side egress escapes; there was no difference for one-man escapes. For two-man escapes only the Steinke Hood yielded significant differences in escape times across configurations. These relation-

ships are summarized in Figure 8. For the Steinke Hood and the SEIS the linear component of the interaction between team size and trunk configuration was significant. The increase in mean escape time as team size increases is linear for both the tube egress type and the side egress type configurations. The slopes of the curves are different, and the curves diverge. The trend analysis indicates that the effect of an additional man would be to increase the mean required escape time. From the least squares regression lines fitted to the data for one, two, and three-man teams, it is possible to predict to a four-man escape. These regression lines are plotted in Figure 9.

In the initial conception of the study, the side egress configuration was considered to be the easiest to escape from because of the absence of the escape tube and the placement of the hatch. The superiority of tube egress to side egress was not anticipated. There are several variables which may have effected this difference: the presence of decking with
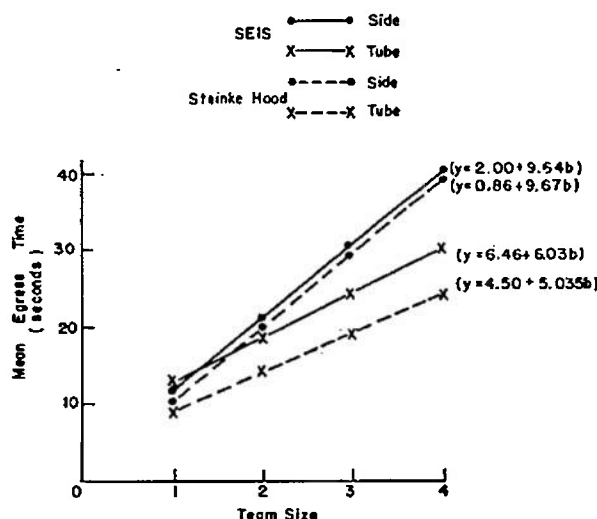
15

SEIS ●———● Side
X———X Tube

Steinke Hood ●----● Side
X----X Tube

(y = 2.00 + 9.54b)
(y = 0.86 + 9.67b)
(y = 6.46 + 6.03b)
(y = 4.50 + 5.035b)

Fig. 9. Regression curves for one, two and three-man escapes from side egress and tube egress escape trunks with the SEIS and Steinke Hood.

the side egress configuration; differences in escape techniques imposed on the escapee by the two configurations; the difference in the diameter of the two trunks. Since there was no significant difference in speed of egress between the tube and the side configurations in single man escapes, the first two variables do not appear to be the major parameters operating here. The relative diameter of the trunks interacting with team size would seem to be the critical variable.

An additional parameter which was of concern was whether the position of an S within a team had any effect upon his escape time, i.e., did a single man escape faster than the first man in a two-man or three-man team. Across team sizes, no significant differences were found in escape time for the first man or the second man with either appliance. The significant differences in escape time between one-man, two-men, and

three-men can be attributed only to the total number of men present in the escape trunk.

In interpreting Figures 8 and 9, it must be recognized that the escape times have not been corrected to reflect the variances and that the population of Ss used in the present study was that of highly trained and experienced divers. Speed of egress with this level of training and experience would be expected to be considerably more rapid than that which would be obtained with the population of submariners as a whole. Also, in the present study the Ss wore only swimming trunks. In a normal escape evolution, the escapee would wear dungarees or other clothing and a special diaper is used with the SEIS for absorption purposes. Because the Ss in the present study made sequential escapes, it was not feasible for them to wear either the diaper or the additional clothing. It is conceivable that this apparel could slow down and hamper the escape process resulting in longer egress times than those obtained in the present study.

Escape with the Steinke Hood was somewhat more rapid than with the SEIS. Because of the nature of the experimental design, the difference could not be evaluated statistically. Since the data for the two escape appliances is similar in all other respects, this difference would appear to be attributable to the greater bulk and positive buoyancy[1] of the SEIS and/or to the greater familiarity and experience of the Ss with the Steinke Hood. Because of the small magnitude of the

1. The SEIS has a positive buoyancy of 70 lbs., and the Steinke Hood a positive buoyancy of 45 lbs.

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difference there is no reason to expect that the existing escape capability with the Steinke Hood would be reduced by substituting the SEIS.

For the side egress trunk, the decking was simulated to evaluate its effect upon the speed and difficulty of escape. Although the decking did not seem to be a major variable in the escape procedure, several instances were observed of $\underline{S}$s hitting their heads upon the decking in a way which could have had fatal results in an actual escape. Because of a malfunction in the video tape recording equipment, these instances were not adequately documented.

The data from the present study must be considered in relation to two other variables: the maximum bottom time allowable if one is to guard against decompression sickness, nitrogen narcosis, and carbon dioxide toxicity, and maximum possible compression rate in the escape trunk without lung squeeze. Allowable bottom time decreases with increased depth. Thus, at 50 feet maximum allowable time would be 100 minutes, at 200 feet 3 minutes and 45 seconds, and at 400 feet 1 minute and 50 seconds.[2] Time for compression without irreversible physiological damage is limited to 16 to 20 seconds (Summitt, et.al., 1969; Barnard and Eaton, 1965; Bennett, Dosett, and Ray, 1964) and

_____

2. *The exposure values were computed by D.A. Hall, LT, MSC, USN, using a modified Haldane model with "M" values from Table N, Appendix C in Workman, 1966, and may be conservative. The theoretical values are confirmed by the experience of the Royal Navy (Barnard and Eaton, 1965; Bennett, et. al., 1964; Hamlyn and Toyler, 1967) and the United States Navy (Summitt, et. al., 1969)*

must be subtracted from the allowable bottom time to determine the time available for egress at any specified depth. For a successful escape, available egress time can not be less than the obtained egress times shown in Tables 2 and 6.

In summary, available egress time is determined by the configuration of the escape trunk, the size of the escape team, time required for compression, and depth from which the escape is made. The SEIS provides greater exposure protection than the Steinke Hood (Hall, Noble and Santa Maria, 1968) and the present study indicates that the two appliances provide the same escape capability.

ACKNOWLEDGEMENTS

APPENDIX

Fig. 1. *Configuration of United States Navy Submarine Escape Trunks Designated by Submarine Classification (Engineering and Repair Department, Naval Submarine Base New London, Groton, Connecticut)*

Steinke Hood - Tube Egress

apes t₀	Two Man Escapes			Three Man Escapes			
t_0	Cell	t_1-t_0 First Man	t_1-t_0 Second Man	Cell	t_1-t_0 First Man	t_1-t_0 Second Man	t_1-t_0 Third Man
.0	a-B	11.0	13.0	bc-A	5.8	12.0	18.0
.0	c-A	11.0	19.0	cb-A	9.5	22.0	30.0
.0	b-A	8.0	14.0	ab-C	9.0	14.0	19.0
.0	c-B	6.2	12.0	ca-B	6.5	11.0	17.5
.0	a-C	11.4	16.0	ba-C	12.8	18.0	24.5
.0	b-C	13.5	18.0	ac-B	10.0	14.0	22.3
.3	b-A	12.0	17.2	ab-C	6.0	10.5	15.0
.0	a-C	8.8	12.2	bc-A	12.0	15.0	21.2
.7	c-A	6.0	11.0	ac-B	10.5	14.3	19.0
.0	c-B	4.7	7.5	ca-B	6.0	9.0	14.8
.0	b-C	9.0	13.0	ba-C	9.0	13.0	18.5
.0	a-B	9.0	13.0	cb-A	9.7	12.0	20.0

Steinke Hood - Side Egress

t₀	Cell	t_1-t_0 First Man	t_1-t_0 Second Man	Cell	t_1-t_0 First Man	t_1-t_0 Second Man	t_1-t_0 Third Man
.0	a-B	11.3	18.0	ab-C	8.3	18.0	31.0
.0	a-C	12.0	25.0	ca-B	14.0	24.7	32.0
.2	b-C	11.0	21.0	cb-A	16.0	21.5	30.7
.0	c-B	8.7	15.0	ac-B	9.0	16.0	26.0
.0	c-A	10.0	18.0	ba-C	7.0	17.0	27.0
.0	b-A	9.0	16.7	bc-A	9.0	22.0	35.3
.0	b-A	9.0	24.7	ca-B	12.7	21.0	30.0
.0	c-A	14.0	28.1	ab-C	11.0	18.5	30.7
.0	b-C	9.6	23.6	cb-A	10.7	15.0	23.0
.0	c-B	15.3	23.0	ba-C	10.0	22.8	30.0
.0	a-B	12.0	21.0	bc-A	8.3	18.0	24.7
.0	a-C	14.0	23.0	ac-B	10.0	24.0	31.0

be Egress

o Man Escapes		Three Man Escapes					One Man Esca	
t_1-t_0 First Man	t_1-t_0 Second Man	Cell	t_1-t_0 First Man	t_1-t_0 Second Man	t_1-t_0 Third Man	Group	Cell	t_1-
18.0	32.0	cb-A	18.0	28.0	41.0	1	C	5.
15.8	24.0	ba-C	23.2	28.0	30.0		A	12.
18.0	25.0	ca-B	14.0	23.0	37.0		B	14.
13.0	28.0	ac-B	18.0	25.0	37.0		C	10.
17.0	49.0	bc-A	15.0	22.0	33.0		A	9.
18.0	35.0	ab-C	15.0	25.0	34.0		B	14.
14.0	22.0	cb-A	13.8	16.2	28.0	2	A	8.
8.0	16.5	bc-A	7.3	14.0	22.5		A	9.
11.0	15.0	ba-C	9.0	16.0	22.7		C	8.
8.0	15.5	ab-C	7.3	14.0	22.0		C	10.
8.0	12.3	ac-B	10.0	15.0	22.0		B	9.
11.2	17.0	ca-B	11.5	17.0	27.0		B	10.
12.0	24.3	ab-C	18.0	24.0	31.7			
11.7	22.0	ca-B	12.0	17.0	24.5			
7.0	15.0	cb-A	12.7	16.5	22.2			
9.0	15.0	ba-C	7.0	15.0	19.5			
8.8	11.0	ac-B	10.2	23.0	26.0			
6.0	11.0	bc-A	8.0	13.6	17.0			
11.0	23.0	bc-A	13.0	20.0	27.7	1	A	10.
11.0	18.0	cb-A	8.0	12.0	19.0		A	14.
11.0	18.3	ab-C	4.5	10.0	18.3		B	6.
11.0	19.3	ca-B	6.0	12.0	17.0		B	11.
10.0	17.0	ba-C	7.3	13.0	19.0		C	13.
10.0	19.0	ac-B	6.0	11.3	15.5		C	10.
9.5	22.0	ab-C	12.0	15.0	19.0	2	B	8.
9.0	13.0	bc-A	7.0	10.2	18.0		B	8.
7.0	14.0	ac-B	7.0	11.0	15.0		C	8.
7.0	11.0	ca-B	7.0	13.0	17.3		A	10.
8.0	13.0	ba-C	9.7	14.2	18.0		A	7.
6.0	11.0	cb-A	9.0	12.0	19.2		C	14.

Table 1. Raw Data: Table of (

:s   SEIS - Tube Egr

d	Three Man Escapes				Group	One Man Escapes		Two Man	
	Cell	t_1-t_0 First Man	t_1-t_0 Second Man	t_1-t_0 Third Man	Group	Cell	t_1-t_0	Cell	t_1-t_0 First Man
)	ca-B	8.0	23.0	31.0	1	A	25.0	a-B	18.0
)	bc-A	5.0	10.0	20.0		C	18.0	a-C	15.8
)	cb-A	6.3	16.0	26.8		A	14.0	c-A	18.0
)	ac-B	9.7	17.0	26.0		C	12.3	b-C	13.0
0	ba-C	7.0	16.0	22.3		B	16.0	c-B	17.0
0	ab-C	8.0	17.0	24.0		B	15.0	b-A	18.0
0	cb-A	10.5	27.0	35.3	2	B	10.7	c-B	14.0
0	ab-C	4.3	14.0	26.0		C	13.0	b-C	8.0
8	bc-A	17.0	30.0	36.0		C	9.0	a-C	11.0
0	ca-B	13.0	22.0	38.0		B	12.0	b-A	8.0
0	ac-B	6.2	19.0	35.5		A	9.0	c-A	8.0
5	ba-C	12.0	20.0	36.0		A	12.0	a-B	11.2
0	ba-C	21.0	28.0	43.0	3	B	13.0	b-A	12.0
0	ab-C	13.0	25.0	37.6		A	14.0	c-A	11.7
0	bc-A	11.5	23.0	35.0		A	10.0	a-B	7.0
0	ca-B	8.0	17.0	27.5		C	12.0	a-C	9.0
3	ac-B	9.0	18.0	27.5		B	8.0	c-B	8.8
0	cb-A	7.0	17.0	25.0		C	11.0	b-C	6.0
5	ca-B	11.3	21.7	29.3	4	C	7.3	a-B	11.0
2	ab-C	6.2	15.0	24.0		A	9.0	c-A	11.0
0	cb-A	11.8	20.0	28.0		B	8.0	b-A	11.0
4	ac-B	9.0	19.0	26.5		C	9.0	c-B	11.0
0	bc-A	8.0	17.0	26.0		A	17.0	a-C	10.0
0	ba-C	11.0	27.0	40.0		B	14.0	b-C	10.0
0	ab-C	10.0	18.7	34.0	5	A	11.0	b-A	9.5
.0	ca-B	4.3	14.3	25.4		A	11.0	a-C	9.0
.2	cb-A	15.5	25.0	37.0		C	9.0	c-A	7.0
.3	ac-B	11.2	26.0	37.0		C	10.0	c-B	7.0
.3	ba-C	10.0	18.5	34.0		B	8.0	b-C	8.0
.0	bc-A	12.0	23.6	33.6		B	11.0	a-B	6.0

	SEIS - Side Egress					
	One Man Escapes		Two Man Escapes			
Group	Cell	t_1-t_0	Cell	t_1-t_0 First Man	t_1-t_0 Second Man	Cell
1	B	8.0	c-B	8.0	17.0	ca-E
	C	8.0	b-C	9.0	17.0	bc-A
	A	9.0	c-A	8.0	17.0	cb-A
	C	8.0	a-C	8.0	16.0	ac-E
	A	8.0	a-B	5.0	13.0	ba-C
	B	7.0	b-A	7.0	14.0	ab-C
2	A	8.1	b-C	15.6	27.0	cb-A
	A	14.0	b-A	10.0	23.0	ab-C
	C	9.0	c-A	15.5	26.8	bc-A
	B	12.0	a-C	6.7	17.0	ca-E
	C	20.0	c-B	18.0	33.0	ac-E
	B	22.0	a-B	7.0	27.5	ba-C
3	C	23.0	b-C	18.0	32.0	ba-C
	B	15.0	a-C	10.0	24.0	ab-C
	B	12.0	c-B	6.0	18.0	bc-A
	A	8.0	b-A	11.0	21.0	ca-E
	A	12.0	a-B	11.0	22.3	ac-E
	C	8.0	c-A	9.0	19.0	cb-A
4	A	14.0	a-B	10.0	20.5	ca-B
	A	10.0	a-C	11.0	20.2	ab-C
	B	8.0	b-C	7.0	15.0	cb-A
	B	7.0	c-B	9.0	18.4	ac-E
	C	11.0	c-A	11.0	19.0	bc-A
	C	8.0	b-A	8.0	17.0	ba-C
5	B	16.5	b-A	16.0	31.0	ab-C
	B	11.0	c-A	16.0	27.0	ca-B
	C	19.0	b-C	14.0	27.2	cb-A
	A	12.0	c-B	7.0	15.3	ac-E
	A	11.3	a-B	9.0	17.3	ba-C
	C	10.0	a-C	13.0	27.0	bc-A

[1] All times are in seconds

72 ft

597 fwd
598 aft

608
616
640
aft

sification
t)

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13. ABSTRACT

The compatibility of the British Mark VII Submarine Escape Immersion Suit (SEIS) with side egress and tube egress United States Navy escape trunk configurations was evaluated. Egress time with the SEIS was compared to that with the Steinke Hood under conditions of individual and group escape (1, 2, and 3 man teams). Escape time increased linearly as a function of team size. For both escape appliances a significant interaction was obtained between escape trunk configuration and team size. More rapid escapes were made by three-man teams from tube egress than from side egress escape trunk configurations; there was no difference for one-man escapes. For two-man teams, escapes were more rapid from the tube egress configuration with the Steinke Hood; there was no difference between configurations with the SEIS. While the depth from which escapes can be made without danger of adverse physiological effects is limited by the size of the escape team and the trunk configuration, there is no evidence to indicate that existing escape capability with the Steinke Hood would be reduced by substituting the SEIS which provides greater exposure protection.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Human Factors in Submarine Escape						
Submarine Escape						
Submarine escape suits (British Mark VII) evaluation of						
Protective Suits for Submarine Personnel						
Simulation of Submarine Escape						
Escape Trunk Configuration						
Submarine Escape Appliances						
Steinke Hood						